Measurement

* Every measurement carries an uncertainty

Balance

certainty up to 0.1

$$W = \boxed{83.4 \mp 0.1 \text{ kg}}$$

• Units

Basic units

time	length	Mass
seconds	meters	kilograms

[Force] → Newtons = kg m/s²

[momentum] = kg m/s

[kinetic Energy] = kg m²/s²

Derived units

[Temperature] ⟹ Kelvin

[Temperature] → Kelvin
k_B → Boltzmann
J

Second: Is the time required for 9 192 631 770 oscillations of Cs atom's fundamental excitation!

The error in atomic clocks is 1 part in 10^{15}

$\Rightarrow$ improve the accuracy to 10^{18}

Length: meters

Meter is the length traversed by light in $\frac{1}{299\,792\,458}$ of a second! in vacuum!

Mass: kg

1 kg is the mass of the cylinder at SI Headquarters at Paris

Mass of a single atom C^{12}
can be measured very precisely.

Significant figures

$\underbrace{83.0}_{\text{3 significant figures}}$ kg

$\underbrace{83\ \text{kg}}_{\text{2 significant figures.}}$

$\cancel{65\,000\,000}$ vs $\underbrace{65\,000\,003}$

$\underbrace{6.5}_{\text{2 significant figures}}\ 10^7$ years

$6.5000003\ 10^7$ years

$L_x = 6$ m (1)

$L_y = \underbrace{3.0}_{\text{2 sign fi}}$ m

$$A = L_x L_y$$
$$= 6 \times 3.0$$
$$= 18.\cancel{0}\ m^2$$
$$\simeq 2\ 10^1\ m^2$$

$$\begin{array}{r} 6.0 \\ \times\ 3.6 \\ \hline 18.00 \end{array} \qquad \begin{array}{r} 6.9 \\ \times\ 3.0 \\ \hline 20.70 \end{array}$$

* Generally if significant

* Generally if significant figures are not expressly given give at least 2 significant figures.

$$\frac{20.0\,m}{3.0\,s} = \boxed{\underbrace{6.7}_{\text{significant figures}}\ \underbrace{m/s}_{\text{units}}}$$

Dimensional Analysis

$$[T] = \text{Newton}$$

$$= kg\, m/s^2$$

$$[T] = [M]^a [L]^b [V]^c$$

$$[T] = kg^a\, m^b\, \frac{m^c}{s^c} = kg\,\frac{m}{s^2}$$

$$a = 1$$

$$b + c = 1 \Rightarrow b = -1$$

$$c = 2$$

$$T = M L^{-1} v^2 = \boxed{\frac{M v^2}{L}}$$

Order of magnitude estimates

Scientific Notation

$6.02 \; 10^{23}$ order of magnitude.

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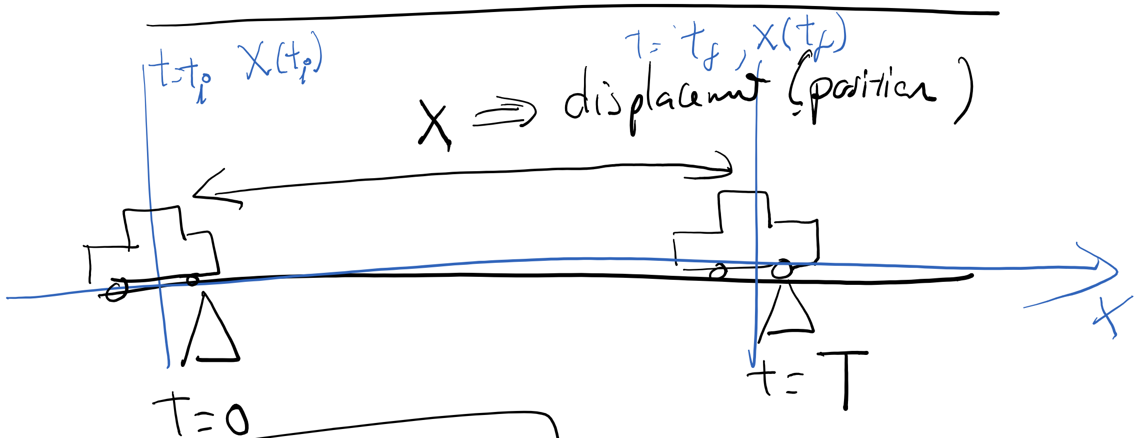
1 Dimensional Motion

$x \Rightarrow$ displacement (position)

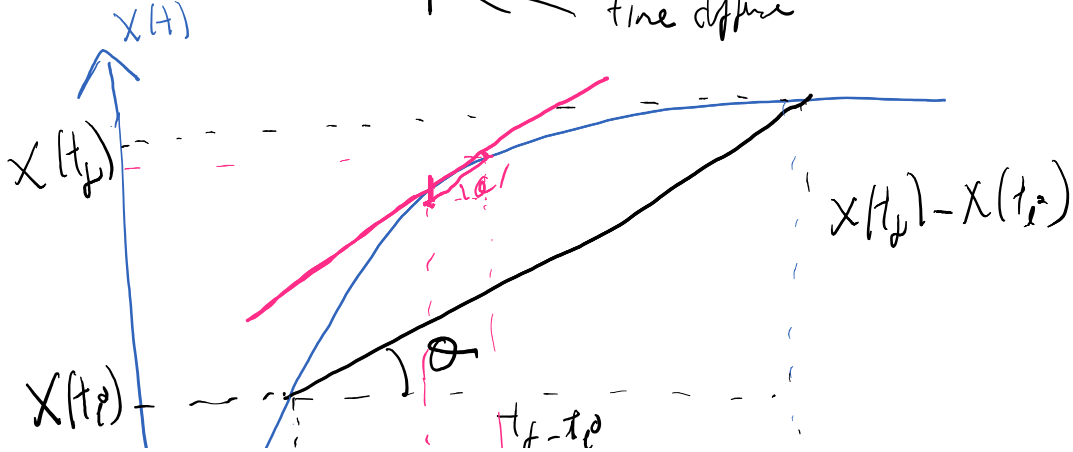


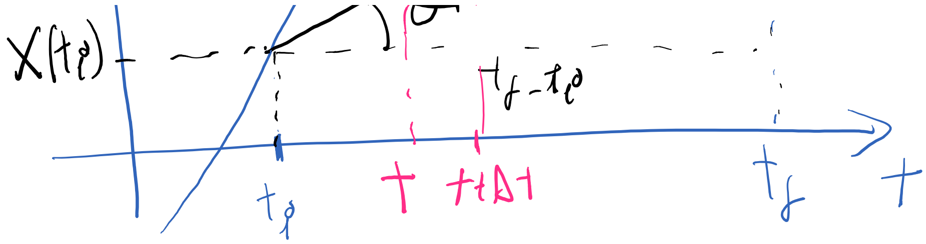
$$\boxed{x(t) = ?}$$ → trajectory

displacement

$$V_{av} = \frac{x}{T} = \frac{x(t_f) - x(t_i)}{t_f - t_i}$$

T ← time difference





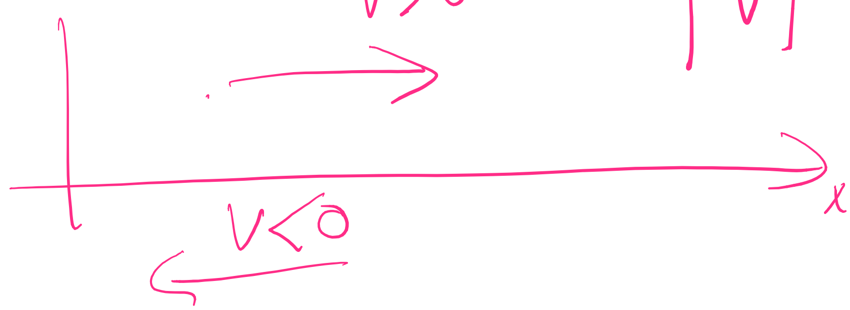
$$V_{av} = \tan\theta \,!$$

$$V(t) = \frac{x(t+\Delta t) - x(t)}{\cancel{t}+\Delta t - \cancel{t}} = \lim_{\Delta t \to 0} \frac{x(t+\Delta t) - x(t)}{\Delta t}$$

$$\boxed{V(t) = \frac{d\,x(t)}{dt}}$$

velocity.

$$|V| \to \text{Speed}$$



PHYSICS 101- Instructor: M. Özgür OKTEL - 2016

$$10^{24} \leftrightarrow 10^{26} \leftrightarrow 10^{28}$$

QUIZ-1

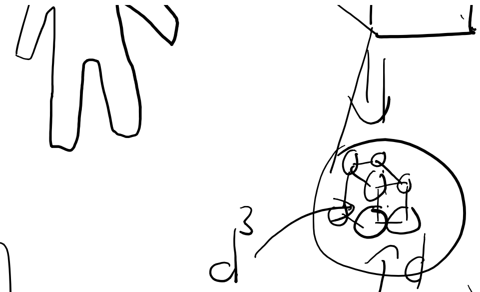
Estimate the number of atoms in your instructor within two orders of magnitude using the following information:

$$V = \frac{M}{\rho}$$

- Your instructor's mass is approximately 80 kg.
- The density of humans is approximately 1.02 g/cm^3
.
- The average distance between atoms in a liquid or solid is 1 *nanometer.*

M ρ d

$M \quad \rho \quad d$



$$N \sim \frac{V}{d^3} = \boxed{\frac{M}{\rho d^3}}$$

1°) Gad ✓

2°) Units ✓

3°) $M \to \infty$ ✓
$N \to \infty$
$d \to 0$ ✓
$N \to \infty$
Limits ✓

$$\left[\frac{M}{\rho d^3}\right] = \frac{kg}{\cancel{\frac{kg}{m^3}}\,\cancel{m^3}} \checkmark$$

$M = 80\,kg$ $\quad \rho = 1.02\ g/cm^3 \quad d = 1\ nm$

$= 8\,10^1$

$= 1.02\,10^{-3}\ kg/cm^3 \qquad = 10^{-9}\ m$

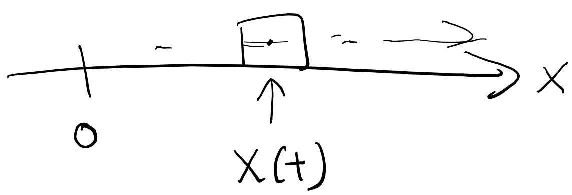
$= 1.02\,10^{3}\ kg/m^3 \qquad 1\,cm = 10^{-2}\,m$

$1\,cm^3 = 10^{-6}\,m^3$

$$N \simeq \frac{8\,10^1}{\cancel{1.02}\,10^3\,(10^{-9})^3} \simeq 8\,10^{-2}\,10^{27} = \boxed{8\,10^{25}} \Longrightarrow 10^{26}$$

$8\,10^{23} \sim 8\,10^{27}$

Position, Velocity and Acceleration.



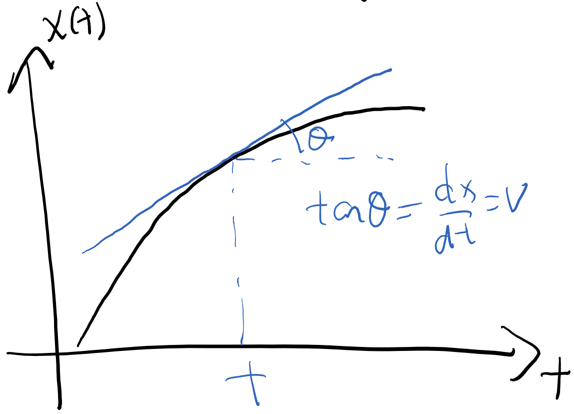
$$\boxed{[V] = \frac{m}{s}}$$

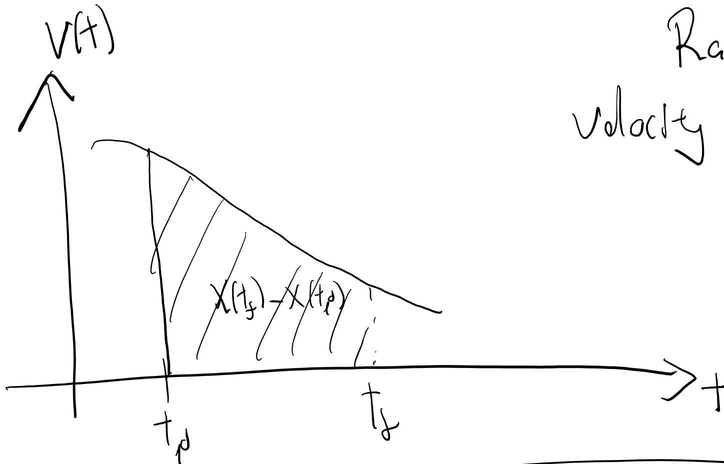
$$V = \frac{X(t_f) - X(t_i)}{} \xrightarrow[t_f \to t_i]{\lim} \boxed{V(t) = \frac{d}{dt}(X(t))}$$

$$V_{avg} = \frac{x(t_f) - x(t_i)}{t_f - t_i} \xrightarrow[t_f \to t_i]{\lim} \boxed{V(t) = \frac{d}{dt}(x(t))}$$

$$\Downarrow$$

$$\boxed{x(t_f) = \int_{t_i}^{t_f} V(t)\,dt + x(t_i)}$$





Rate of change of velocity $\Rightarrow$ $\boxed{\text{acceleration}}$

Average acceleration

$$a_{avg} = \frac{V(t_f) - V(t_i)}{(t_f - t_i)}$$

acceleration

$$\xrightarrow[t_f \to t_i]{\lim} \boxed{a(t) = \frac{dV(t)}{dt}}$$

$$\boxed{V(t_f) = \int_{t_i}^{t_f} a(t)\,dt + V(t_i)}$$

$[a] = \frac{m/s}{s}$

$[a] = m/s^2$

$V = \frac{dx}{dt}$ $\qquad a = \frac{dv}{dt}$ $\qquad$ "jerk" $\frac{da}{dt}$

$x(t) \rightarrow V(t) \rightarrow a(t) \rightarrow$

F ma

$$x(t) \qquad v(t) \qquad a(t)$$

$$\boxed{F = ma}$$

$$x(t_f) = \int_{t_i}^{t_f} v(t)\,dt + x(t_i) \qquad v(t_f) = \int_{t_i}^{t_f} a(t)\,dt + v(t_i)$$

$v(t=0)=0$

Example For an object which is stationary at time $t=0$ at $x=0$ the acceleration is given as $\boxed{a(t) = \alpha t}$

$[a] = m/s^2 = [\alpha]\,s$

(a) What are the correct SI units for α? $\boxed{\alpha = m/s^3}$

(b) Find $v(t) = ?$

(c) Find the position of the particle at time t.

(b) $$v(t_f) = \int_0^{t_f} a(t)\,dt + \underbrace{v(t=0)}_{0}$$

$$v(t_f) = \int_0^{t_f} \alpha t\,dt = \alpha \int_0^{t_f} t\,dt = \alpha \frac{t^2}{2}\Big|_0^{t_f}$$

$\int_0^{t} t\,dt$ — limit — integration variable

$$v(t_f) = \frac{\alpha}{2} t_f^2$$

$$\boxed{v(t) = \frac{\alpha}{2} t^2}$$

(c) $x(t) = ?$

$$x(t_f) = \int^{t_f} v(t)\,dt + \underbrace{x(t=0)}$$

$$\int t^n dt = \frac{t^{n+1}}{n+1}$$

$$x(t_f) = \int_0^{t_f} V(t)\,dt + \underbrace{x(t=0)}_{0}$$

$$= \int_0^{t_f} \frac{\alpha}{2} t^2\,dt = \frac{\alpha}{2}\int_0^{t_f} t^2\,dt$$

$$= \frac{\alpha}{2}\frac{t^3}{3}\Big|_0^{t_f} = \frac{\alpha}{6} t_f^3$$

$$\boxed{x(t) = \frac{\alpha}{6} t^3}$$

$$[x] = m = \underbrace{[\alpha]}_{\frac{m}{\cancel{s^3}}}[t]^3 \quad \cancel{s^3} \checkmark$$

1°) Good ✓

2°) Units ✓

3°) Limits ✓

$t \to 0$ $\quad V \to 0$, $x \to 0$ ✓

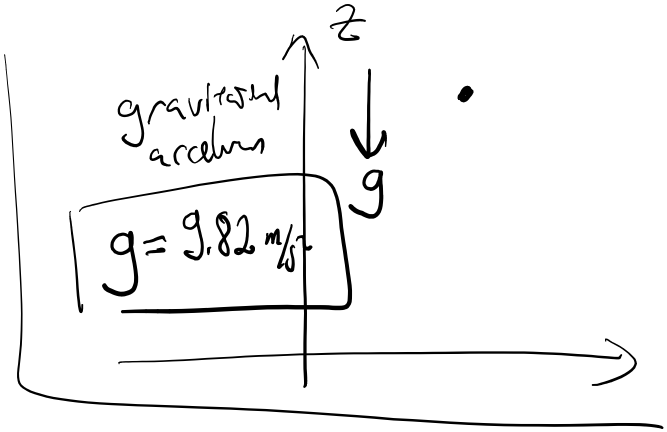
Motion with constant acceleration

$$a(t) = a$$

$$V(t_f) = \int_0^{t_f} a\,dt + \underbrace{V(t=0)}_{V_0}$$

$$V(t_f) = a\underbrace{\int_0^{t_f} dt}_{t\big|_0^{t_f}} + V_0$$

$$\boxed{V(t) = at + V_0}$$



$$x(t_f) = \int_0^{t_f} V(t)\,dt + \underbrace{x(t=0)}_{x_0}$$

$$\Longrightarrow \quad x(t_f) = \int_0^{t_f} (at + V_0)\,dt + x_0$$

$$= \int_0^{t_f} at\,dt + \int_0^{t_f} V_0\,dt + x_0$$

$$X(t_f) = a\frac{t_f^{3}}{2} + V_0 t_f + y_0$$

$$\boxed{X(t) = \frac{1}{2}at^2 + V_0 t + X_0}$$